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Ambient Odor Testing of Concentrated Animal Feeding Operations Using Field and Laboratory Olfactometers

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Abstract

The Missouri Air Conservation Commission regulations include regulations that limit the amount of acceptable odor from Confined Animal Feeding Operations (CAFOs). The regulations concerning odor designate the use of a scentometer as a screening tool. The rules dictate if an odor is detectable by an investigator at a dilution ratio of 5.4 using a scentometer then an air sample should be collected and sent to an olfactometry laboratory for an odor panel to determine the detection threshold and the intensity of the odor sample. The detection thresholds are determined following ASTM E679-91 and EN13725. The Intensity is determined following ASTM E544-99. If the olfactometry laboratory determined the detection threshold of the sample to be above 7 then the CAFO would be in violation. If the olfactometry laboratory determined the intensity level to be above a level equivalent to 225 PPM of n-butanol then the source of odor would be in violation.

The CAFO odor rules came under scrutiny by representatives of the largest hog producer in the State of Missouri. Specifically they argued the detection threshold limit of 7 in the CAFO portion of the rule was too low for the rule to realistically identify a violation.

This paper presents the results of a study to find the appropriate regulatory level of odor as determined by laboratory olfactometry. The study took place from November 2001 through October 2002. Samples were collected from field locations that exhibited odor produced by confined animal feeding operations and from areas exhibiting no apparent odor. The odors were categorized based upon the scentometer level at which the odors were detectable and then samples were sent to an odor evaluation laboratory for analysis by olfactometry.

Keywords
Regulations; Scentometer; olfactometry; dilution-to-threshold

INTRODUCTION

The Missouri Air Conservation Commission regulations include regulations that limit the amount of acceptable odor from Confined Animal Feeding Operations (CAFOs). Odor is addressed in the following regulations listed in the Missouri Air Pollution Control Program Laws and Regulations, Missouri Department of Natural Resources; 10 CSR 10-2.070, " Restriction of Emission of Odors", 10 CSR 10-3.090, "Restriction of Emission of Odors," 10 CSR 10-4.070, " Restriction of Emission of Odors" and 10 CSR 10-5.160, "Control of Odors in the Ambient Air" (Missouri Code of State Regulations, Missouri Department of Natural Resources-Air Pollution Control Program Laws and Regulations).

The regulations concerning odor designate the use of a scentometer (field olfactometer) as a screening tool. The rules dictate if an odor is detectable by an investigator at a dilution ratio of 5.4 parts of carbon filtered air to 1 part odor laden air with a scentometer, then an air sample should be collected and sent to an olfactometry laboratory. The olfactometry laboratory then uses an odor panel to determine the detection threshold and the intensity of the odor of the sample. The detection thresholds are determined following ASTM methodology (ASTM Standard Practice E679-91) and accepted European methodology (European Standard, EN 13725). The Intensity is determined following ASTM methodology (ASTM Standard Practice E544-99). If the olfactometry laboratory determined the detection threshold of the sample to be above 7 then the CAFO would be in violation. If the olfactometry laboratory determined the intensity level to be above a level equivalent to 225 PPM of n-butanol then the source of odor would be in violation. The rules concerning CAFOs were to be fully implemented by January 1, 2002.

The CAFO odor rules came under scrutiny at the December 6, 2001, Missouri Air Conservation Commission (MACC) meeting. Representatives of the largest hog producer in the State of Missouri, Premium Standard Farms (PSF), voiced concerns with the wording of the rule, specifically the detection threshold limit of 7 in the CAFO portion of the rule (10 CSR 10-3.090(5)(C)(2)(A)). PSF and the Missouri Department of Natural Resources, Air Pollution Control Program (APCP) independently determined that the laboratory olfactometry detection threshold of 7 in the rule was too low for the rule to realistically identify a violation. (Missouri Air Conservation Commission Briefing Document, December 6, 2001)

This paper presents the results of the study to find the appropriate regulatory level of odor as determined by laboratory olfactometry. The study took place from November 2001 through October 2002. Samples were collected from field locations that exhibited odor produced by confined animal feeding operations and from areas exhibiting no apparent odor. The odors were categorized based upon the scentometer level at which the odors were detectable and then samples were sent to an odor evaluation laboratory for analysis by olfactometry.

METHODS

Research was conducted to determine if the numbers used in the rule are too low for the regulatory standard. The purpose of this study was to determine a laboratory detection threshold number to correlate with a 7:1 scentometer level to insure consistency in the odor-related rules.

The research included collection of ambient air samples. Scentometer readings and air samples for olfactometry determination were collected in the field. An appropriate detection level was determined from this research and presented at the Missouri Air Conservation Commission April meeting. (Missouri Air Conservation Commission Briefing Document, April 24, 2003)

The Olfactometry results were evaluated using a single factor ANOVA and Tukey/Kramer Analyses.

Materials

The device used to determine the on site odor level was the scentometer developed by Barneby and Sutcliffe (Barneby & Sutcliffe Designation – Model SCC, U.S. Public Health Designation – Scentometer Model 1959-A), which is shown in Figure 1. Clear packing tape (Manco®, Inc.) was used to cover the closed holes. The manufacturer instructions were used to determine the detection threshold on site. The following Scentometer levels were used for the study, 31:1, 15:1, 7:1, 5.4:1, and 2:1. In addition to the levels developed by the manufacturer, the 5.4:1 ratio was used. This ratio was included due to its inclusion in the Odor Rules (10 CSR 10-2.070, 10 CSR 10-3.090, 10 CSR 10-4.070, 10 CSR 10-5.160). In order to achieve a 5.4 : 1 ratio (clean air to odorous air) the following holes were left open; the two carbon ports on the top and bottom of the scentometer, the 1/16 inch opening, the 1/8 inch opening, and the 1/4 inch opening (see Figure 2).

Figure 1. The Scentometer Field Olfactometer (Barnebey Sutcliffe Corp.). Note the two glass nostril ports to the left and the series of orifice holes at the back of the unit to the right in this photo.

Figure 2. A diagram of the holes to be covered is below for a 5.4:1 dilution using a Barnebey Sutcliffe model 1959 scentometer. X = holes to be covered, O= holes left open

X	O	O	X	O	X

A pre-production model of St. Croix Sensory Inc.'s Nasal Ranger® was also utilized during parts of the investigation. A comparative evaluation was made between the Nasal Ranger (shown in Figure 3) and the scentometer. All final determinations of on site odor detections were done with the scentometer.

Figure 3. The Nasal Ranger® Field Olfactometer (St. Croix Sensory, Inc.). The inset picture shows a close-up of the orifice dial, which is located to the right side of the Nasal Ranger in this photo.

The device used to collect air samples was the AC'SCENT Vacuum Chamber purchased from St. Croix Sensory, Inc. The manufacturer instructions were followed when collecting samples. The samples were collected in 10-liter Tedlar Bags.

Sample Collection was conducted using the following procedure. The investigator determined the area of odor. This possibly involved discussion of the issue with a nearby resident beforehand or traveling through a known odorous area (such as properties owned by confined animal feed operations) while trying to detect an odor. Upon determining the sample sites the investigator arrived at the screening with the car windows closed. The investigator while still in the car would then breathe through the scentometer with only the carbon ports open. Breathing the carbon-filtered air of the scentometer was done to maintain sensitivity of the olfactory nerve endings. Upon exiting the car, with the scentometer in place, the investigator oriented him/herself facing the nearest source of potential odor. The investigator then began at the 170:1 dilution ratio and proceeded through all detection levels through 2:1. The investigator inhaled deeply through his nose to determine if an odor was present. The level at which odor was detectable was recorded.

Samples were collected day or night and shipped within 24 hours of collection.

Samples were collected April 2002-October 2002 throughout the state of Missouri. Samples were collected at the following sites: Wilder Cemetery, Mercer County, Missouri, USA; Premium Standard Farms (PSF) Somerset facility, Mercer County, Missouri, USA; PSF Whitetail Facility, Putnam County, Missouri, USA; Wes Craven property, Worth County, Missouri, USA; MOARK facility on Highway F McDonald County, Missouri, USA; Sharpe Land and Cattle, Lewis County, Missouri, USA. Samples were sent to St. Croix Sensory, Inc. for olfactometry analysis via United Parcel Service (UPS) Next Day Air delivery.

St. Croix Sensory, Inc. analyzed all samples as part of a grant in kind to the Missouri Department of Natural Resources. St. Croix Sensory, Inc. determined the detection threshold, following ASTM International E679 and CEN standard EN13725, and the intensity, following ASTM International E544-99, of each sample utilizing olfactometry techniques.

The samples were statistically analyzed using a Single Factor Analysis of Variance (ANOVA) and confidence intervals for the means were determined. The confidence interval was determined in the following way (Freund, 1988)

$$\bar{x} - Z_{\alpha/2} * \sigma/\sqrt{n} < \bar{x} < \bar{x} + Z_{\alpha/2} * \sigma/\sqrt{n}$$

RESULTS

The detection threshold data was separated into scentometer levels and the mean and confidence intervals were determined (Figure 4 and Figure 7). The detection threshold data was LOG transformed and the mean and confidence intervals were determined (Figure 5).

In order to determine if there was a detection threshold difference between scentometer levels, a Single Factor ANOVA was performed (α=0.05)(Montgomery, 1991). The detection threshold for each sample was determined by laboratory olfactometry. The detection threshold values were then LOG transformed. The LOG transformed olfactometry detection thresholds were used as the observed values. The analysis was done to determine if there was a difference between the scentometer levels (31:1, 15:1, 7:1, 5.4:1, 2:1) and the control samples collected in areas with no noticeable offensive odor. A significant difference was determined to exist between the groups ($p = 0.004943$)(Table 1). A Tukey/Kramer test was then performed to determine which levels were significantly different from one another. The following differences were found; the 15:1 level (mean=2.11) was significantly different ($p<0.01$) from the control (mean=1.798193) and the 7:1 level (mean=1.97) was significantly different ($p<0.01$) from the control (Figure 6). The 95% and 99% confidence levels for each scentometer level and the controls were determined. (Table 3).

A Single Factor ANOVA was performed using all of the samples (α=0.05). The analysis was done to determine if there was a difference between the scentometer levels (31:1, 15:1, 7:1, 5.4:1, 2:1) and the control samples. The olfactometry Intensity levels were used as the observed values. No significant difference was determined to exist between the groups ($p = 0.585148$).

ANOVA: Single Factor
data: transformed data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
31:1	3	6.12	2.04	0.019
15:1	8	16.87	2.11	0.031
7:1	52	102.38	1.97	0.044
5.4:1	26	51.26	1.97	0.059
2:1	24	45.49	1.895	0.036
control	37	66.53	1.798	0.048

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.08	5	0.22	4.799	0.000435	2.28
Within Groups	6.49	144	0.05			
Total	7.58	149				

Table 1. ANOVA table demonstrating a significant difference (α=0.05, p=0.0004) exists between the scentometer levels.

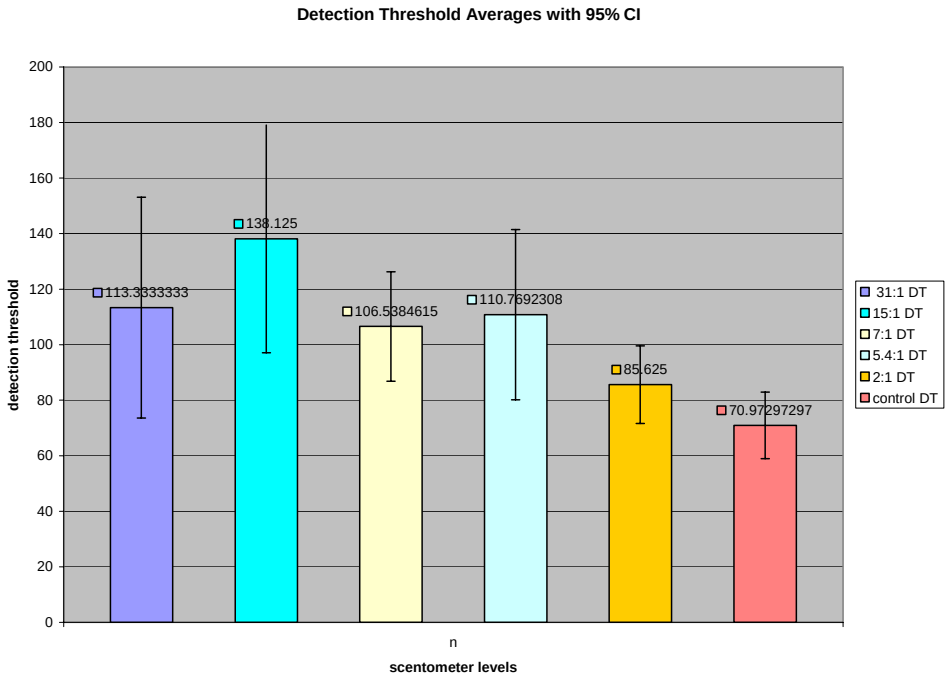

Figure 4. This graph depicts the scentometer levels and ambient air control means. The 95% confidence interval is also depicted.

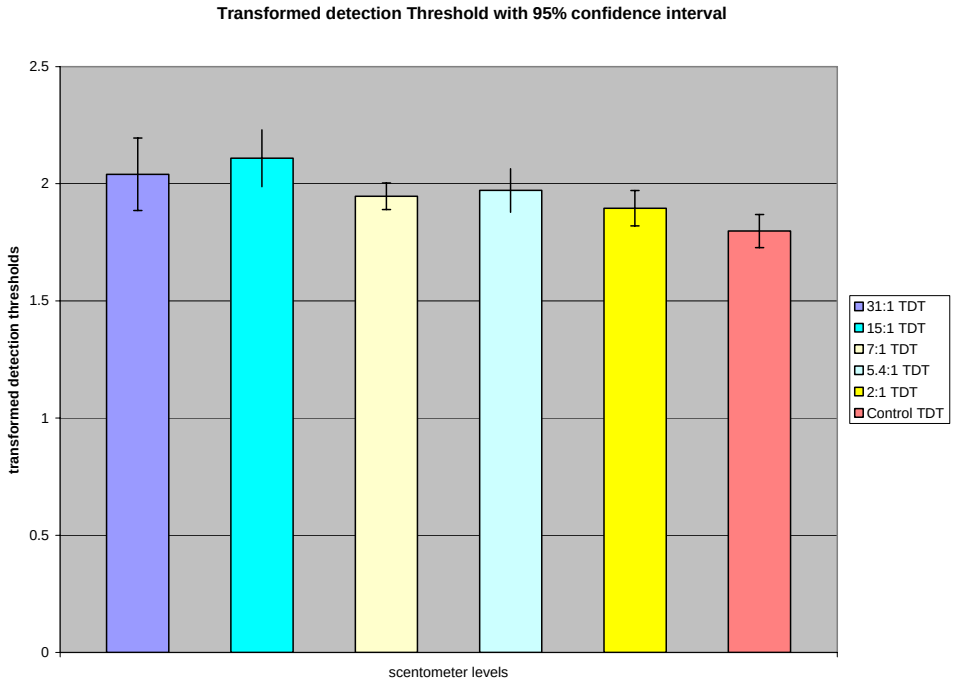

Figure 5. This graph depicts the scentometer levels with the Log 10 transformed detection threshold for each level. The 95% confidence interval is also depicted.

Tukey/Kramer results indicating a significant difference

15:1	7:1	5.4:1	2:1	control	31:1

Figure 6. This figure indicates that the 15:1 level, 7:1 level, and 5.4:1 level are significantly different from the control samples.

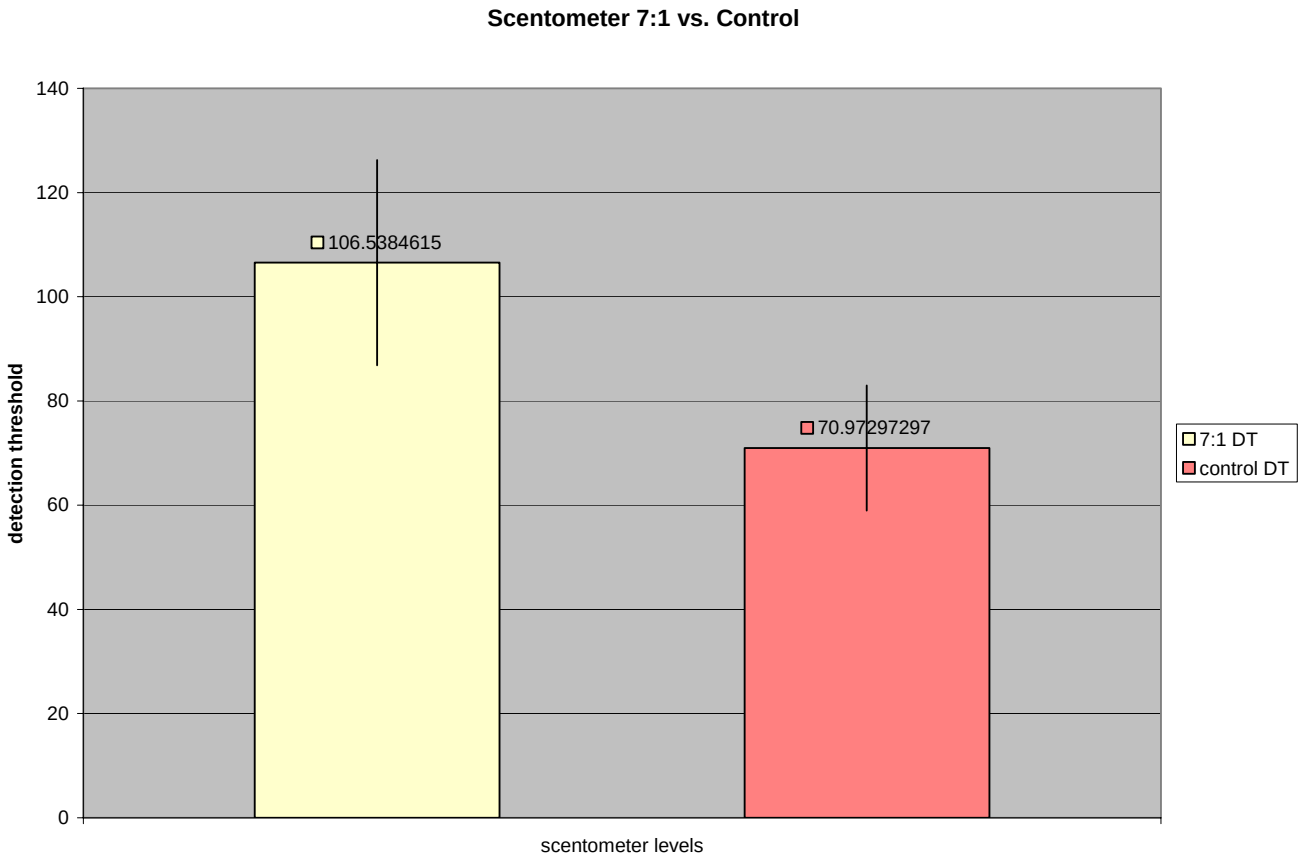

Figure 7. This chart depicts the 7:1 scentometer level averages and the no odor control level average with the 95% Confidence Intervals.

	31:1 DT	15:1 DT	7:1 DT	5.4:1 DT	2:1 DT	control DT	31:1 TDT	15:1 TDT	7:1 TDT	5.4:1 TDT
n	3.00	8.00	52.00	26.00	24.00	37.00	3.00	8.00	52.00	26.00
average	113.33	138.13	106.54	110.77	85.63	70.97	2.04	2.11	1.95	1.97
Max	150.00	260.00	440.00	420.00	160.00	200.00	2.18	2.41	2.64	2.62
Min	80.00	70.00	40.00	35.00	30.00	22.00	1.90	1.85	1.60	1.54
std Dev	35.12	59.16	72.43	79.71	34.90	37.24	0.14	0.17	0.21	0.24
Median	110.00	120.00	87.50	95.00	77.50	70.00	2.04	2.08	1.94	1.98
GEOmean	109.70	128.42	93.08	93.69	78.62	62.83	2.04	2.10	1.96	1.96
95% Cl upper *	153.07	179.12	126.23	141.41	99.59	82.97	2.19	2.23	2.03	2.06
95% Cl lower *	73.59	97.13	86.85	80.13	71.66	58.97	1.89	1.99	1.91	1.88
plus or minus *	39.74	40.99	19.69	30.64	13.96	12.00	0.15	0.12	0.06	0.09
2X std. Dev.	70.24	118.31	144.87	159.42	69.80	74.49	0.27	0.35	0.42	0.48
99%Cl upper *	165.56	192.00	132.41	151.04	103.98	86.75	2.24	2.27	2.72	2.09
99% Cl lower *	61.10	84.25	80.66	70.50	67.27	55.20	1.84	1.95	1.22	1.85
plus or minus *	52.23	53.88	25.88	40.27	18.35	15.77	0.20	0.16	0.75	0.12
* The confidence interval assumed that the samples were large enough n>30 to approximate the sampling distribution of the mean with a normal distribution and where necessary to replace the variance with the sample variance.										

Table 2. This table shows the detection threshold (DT) values determined for air samples collected at different scentometer level values. These values were used for the statistical analyses and determination of the confidence intervals.

A t-Test: Paired Two Sample for Means was performed to determine if a difference existed between the Barnebey and Sutcliffe scentometer and the Nasal Ranger ®. The t-Statistic was determined to be 1.01254 and the critical value was 1.734063(a=0.05). The results of the Barnebey and Sutcliffe scentometer and the Nasal Ranger ® were not found to be significantly different, therefore this study found no evidence the two instruments were not equivalent.

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	6.67	6.11
Variance	19.12	13.88
Observations	19	19
Pearson Correlation		
Hypothesized Difference	Mean 0	
df	18	
t Stat	1.01	
P(T<=t) one-tail	0.16	
t Critical one-tail	1.73	
P(T<=t) two-tail	0.33	
t Critical two-tail	2.10	

Table 3: t-Test: Paired Two Sample for Means results comparing the Barnebey and Sutcliffe scentometer to the pre-production Nasal Ranger®. The results indicated no significant difference (α=0.05, p=0.325) between the instruments.

DISCUSSION

The low sample numbers for some of the scentometer levels may have caused some problems with the analysis. The method in which samples were collected did not allow for all scentometer levels to have the same number of samples. Samples could only be collected when odors were available and the strength of the odors was a factor determined by the source. It would also have been optimal if an equal number of samples could have been collected for each level.

The results for the scentometer level 31:1 were somewhat counter intuitive. One would assume that the stronger odor of the 31:1 level would have had higher detection thresholds. The authors are of the opinion the low sample size of the 31:1 level contributed to this and the low detection threshold were due to random chance. An alternative interpretation is that these were in some way false positives. Given the design

of the Barnebey and Sutcliffe scentometer false positives can be caused by air leaking around the glass nasal ports and the nostril.

The purpose of this exercise was to determine a regulatory limit for CAFO odors that corresponded to the traditional method of using the scentometer regulatory limit of 7:1. The range of the 7:1 values was quite large (40-440) causing the standard deviation to be large. In order to determine an appropriate value, the mean and corresponding 95% confidence interval was determined.

The confidence interval equation required the assumption that the actual variance (σ) was the same as the sample variance. This assumption was deemed valid due to the fact the sample size was large (>30). The mean 106.5 was used to suggest the regulatory limit. At the time of this writing the regulatory limit was determined to be 110 as the detection threshold values from the laboratory are in increments of 5. The geometric mean (93.08) as determined from the transformed data was deemed too low for implementation as a rule.

When discussing whether the Barnebey Sutcliffe scentometer and the St. Croix Sensory Nasal Ranger® are equivalent, the statistical analysis of the results gives a level of objectivity to a rather subjective topic such as odor. There were a few items worth mentioning concerning the Nasal Ranger device, for instance, initially had a distinct 'Plastic-like' smell when unpacked, similar to a new computer or similar piece of equipment. The source of the plastic-smell was hypothesized to be due to out-gassing by the plastic of the device body or the silicone sealant used. The 'plastic-like' smell caused occasional difficulties in distinguishing between the 'plastic-like' smell and the odor detected. The difficulty occurred when odors were very faint such as at the 2:1 level. When the investigator was unable to determine if the odor detected was the 'plastic-like' smell or an outside odor the detection level was deemed inconclusive. In cases such as this the investigator would advance to the next level. Therefore, when comparing the Barnebey/Sutcliffe scentometer to the Nasal Ranger, the Barnebey/Sutcliffe allowed detection at a lower level due to the lack of any 'plastic' smell interference. Over time the Nasal Ranger seemed to 'air-out' and the 'plastic' smell decreased. Currently the smell is not noticeable. As stated previously, the Nasal Ranger ® model used was a pre-production model. St. Croix Sensory, Inc. has since made adjustments to the model and the "plastic smell" is no longer an issue.

In terms of comparing ease of use between the Barnebey and Sutcliffe scentometer and the Nasal Ranger design of the Nasal Ranger makes it much easier to use. The turn dial is particularly useful when going from one level to the next as opposed to covering the intake holes of the Barnebey and Sutcliffe scentometer with adhesive tape or the investigator's fingers. The flow meter light of the Nasal Ranger adds a sense of security that readings are consistent. The nasal mask of the Nasal Ranger ® is definitely more comfortable to use than the glass nasal ports of the Barnebey and Sutcliffe scentometer. The nasal mask also has less leak potential than the glass nasal ports.

CONCLUSIONS

The 7:1 dilution threshold level, as determined by scentometer, was found to be significantly different from the control samples. The appropriate regulatory limit of a laboratory olfactometry determined DT of 110 was determined based upon the mean of odorous air samples collected when a field olfactometer 7:1 dilution-to-threshold was observed.

The Waterlink Barnebey Sutcliffe scentometer and the St. Croix Sensory, Inc. Nasal Ranger® were determined to be equivalent tools for field olfactometry.

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